

## Classification of Magneto-Optic Images using Neural Networks

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Magneto-Optic imaging (MOI) is a new technique for the detection of cracks and corrosion in aircraft skins. A linear current induction mechanism induces eddy currents in the aluminum skin, which are perturbed by surface and subsurface cracks. This generates normal magnetic field components which are imaged by a magneto-optic sensor. A simple Macintosh based imaging system has been developed at NASA Langley Research Center (LaRC) to classify MOI images. The image processing scheme consists of a background subtraction and thresholding to obtain a good contrast between flawed and unflawed regions. An edge detected and a solid silhouette of the resulting image is obtained for classification. Second and third order moments of these two images form the feature space for training a neural network. The next few paragraphs will discuss in detail how this scheme is used to distinguish flawed and unflawed rivets with tiny fatigue cracks in aluminum aircraft skins.

Rapid inspection and classification of aircraft structures for flaws is of vital interest to US industry. MOI is one such device which provides direct visualization of flaws in real time over a  $60\text{cm}^2$  area. The eddy current induction mechanism of the MOI instrument induces eddy currents to flow linearly across the surface of the sample. Flaws are detected by examining the Faraday rotation of polarized light which is transmitted, and then back reflected through a sensor [1,2], which is a magnetic garnet film as shown in Figure 1. A rivet or a surface flaw near a rivet in an aircraft aluminum skin will disturb the magnetic fields, which is then imaged by the analyzer.

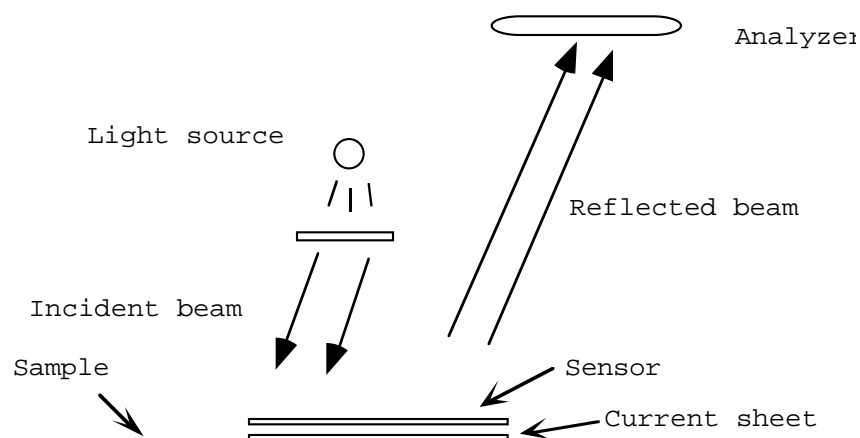


Figure 1. Schematic of the MOI instrument

A Macintosh based imaging system is interfaced with the MOI instrument for improving the raw image, extracting certain unique features from the image and then feeding the information to a neural network for classification. Image enhancement include subtracting a background image for eliminating artifacts due to uneven illumination, median filtering, smoothing and thresholding the resulting image to obtain a clean image of the rivet.

Inverse problems in nondestructive evaluation (NDE) is to extract information relating to defects in the material under test from the response as obtained from a given sensor. Some algorithmic approaches such as neural networks are used as pattern recognition techniques to solve the inverse problem. Artificial neural network model consist of several computational units i.e nodes which are interconnected via weights that are iteratively adapted to improve performance [3,4]. Each simple node performs a weighted sum of the inputs and transforms the sum to an output signal by a nonlinear function. By supplying the network with known signals or patterns of interest and the desired output, the network is 'trained' to generate an optimum set of weights [4]. This is achieved by minimizing the error between the model output and the desired output using a least-squares adaptation algorithm or any other suitable method.

The critical decision for a pattern recognition system is the selection of appropriate features to be extracted from the image for classification. These features should be unique, informative and invariant to translation and rotation of the image. In aircraft structures the rivets are of different sizes and so to it is important that the features should also be size invariant.

Figure 2 shows the raw image from the MOI instrument and the processed image. Fig. 2a. shows images from four typical rivets as the MOI instrument is placed on the aluminum aircraft skin. After enhancing the image as described earlier, a solid silhouette and edge detected image for every rivet is obtained. Fig 2b. shows the image for a typical rivet with a crack, while Fig. 2c shows a rivet with no crack. The next step is to extract from the edge detected image and the solid silhouette image features for training the network to behave as a classifier.

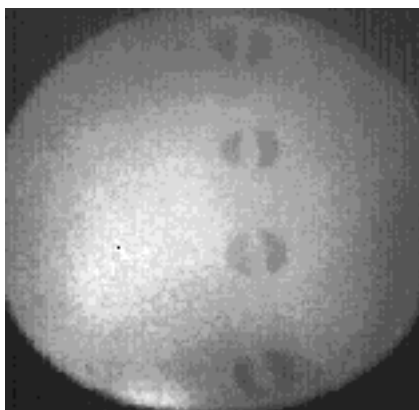


Fig 2a. Typical MOI image



Fig 2b. Solid silhouette and edge detected image of a cracked rivet

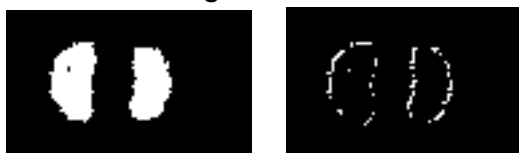


Fig 2c. Solid silhouette and edge detected image of a good rivet

The central moments for either the solid silhouette or edge detected image is given by

$$\mu_{pq} = \frac{1}{N} \sum_{i=1}^N (u - \bar{u})^p (v - \bar{v})^q$$

where N is the number of pixels in the image,  $\bar{u}$ , and  $\bar{v}$  are the mean values of the image coordinates u and v. A set of seven moment invariant functions based on the second and third order moments have been derived by Hu [5] which are invariant under the required transformations. Further Dudani and others [6] modified these moment functions to be independent of size.

Seven moments invariant functions have been obtained for both the solid silhouette and edge detected image of good and cracked rivets from numerous samples. A multilayer perceptron neural network with one hidden layer with 5 nodes, and an output layer with one node is being trained to classify the rivets as good or bad rivets. Three set of feature vectors are being compared for the same set of images to investigate which performs better [7]. The three sets are

1. Six moment invariant functions of the edge detected image,
2. Six moment invariant functions of the solid silhouette image and
3. Combined twelve moment invariant functions from the two images.

## SUMMARY

A real time imaging system with a neural network classifier has been incorporated on a Macintosh computer in conjunction with an MOI system. This system images rivets on aircraft aluminium structures using eddy currents and magnetic imaging. Moment invariant functions from the image of a rivet is used to train a multilayer perceptron neural network to classify the rivets as good or bad (rivets with cracks).

## REFERENCES

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7. Work in Progress.